

PUU MAKAAALA NATURAL AREA RESERVE

MANAGEMENT PLAN

Natural Area Reserves System

State of Hawaii

Department of Land and Natural Resources  
1151 Punchbowl Street  
Honolulu, Hawaii 96813

January 1989

# Puu Makaala Natural Area Reserve

## Contents

Executive Summary .....	1
I. Introduction .....	2
II. Resources Summary	
A. General Setting .....	3
B. Flora .....	5
C. Fauna .....	12
III. Management	
A. Key Management Considerations .....	13
B. Management Zone Descriptions .....	17
C. Management Programs	
Ungulate Control .....	19
Monitoring .....	24
Non-native Plant Control .....	25
Public Education and Volunteer Support ...	28
D. Boundary Administration and Special Uses ..	29
IV. Budget Summary .....	30
V. Sources .....	32
VI. Acknowledgements .....	33
VII. Appendices .....	34

### Figures

Figure 1: Survey Area .....	4
Figure 2: Natural Communities .....	6
Figure 3: Rare Plants and Animals .....	11
Figure 4: Transect Threat Map .....	14
Figure 5: Management Zones .....	18

### Plates

Plate 1: Undisturbed `Ohi`a/Hapu`u Forest .....	7
Plate 2: Pig Damage ....	16

### Tables

Table 1: Natural Communities .....	5
Table 2: Rare Plants .....	10
Table 3: Rare Birds .....	12

### Appendices

Appendix 1: Transect Specifications/Survey Participants	
Appendix 2: Sample Survey Forms	
Appendix 3: Plant Species List	
Appendix 4: Animal Species List	

Cover Photo - Flowers of the hahanui (Cyanea pilosa).

## EXECUTIVE SUMMARY

In 1970, Hawaii became<sup>1</sup> of the first states in the country to recognize the importance of its unique natural resources by establishing the Natural Area Reserves System (NARS). This plan describes the management program proposed for the Puu Makaala Natural Area Reserve, established in 1981 by Executive Order 3102. This 12,000 acre reserve was established to protect some of the Big Island's best wet native forest and unique geologic features.

The Reserve is located in the Puna and South Hilo districts, ranging from 2,800 to 5,500 feet in elevation. Average rainfall is 100-175 inches and major landmarks include Kulani Cone and Puu Makaala. `Ohi`a/Treefern forests are the dominant vegetation, but koa forests also occur in the Reserve. Regionally, the Puu Makaala Reserve represents an important conservation link between the lower elevation Hawaii Volcanoes National Park and the upper elevation native forests of Kilauea, Kulani, and Upper Waiakea. Rare plants and birds are found in the Reserve and surrounding forest areas.

Because of its size, intensive management of key areas within the Reserve are proposed and prioritized based on the biological resources they contain and the threats to those resources. Pigs constitute the most severe threat as their rooting and wallowing destroy native plants and the ground cover on the forest floor. Such damage limits effective regeneration of native plants, and creates conditions favorable for mosquitos and certain non-native weeds. `Ohi`a dieback continues to have an impact in the Reserve, especially in the lower elevations. Weed invasion in the dieback areas is severe, reducing effective native species regeneration.

The construction of a strategic network of 20 miles of barrier fences is proposed to create five management zones. These fences will also cut off pig access into priority areas and direct predictable movements within the two proposed intensive control zones. Encouraging public hunting and improving access are important components of the control program. Other program areas are:

- 1) Monitoring to evaluate the effectiveness of management work and track significant ecological changes,
- 2) Non-native Plant Control of priority weeds that threaten to invade large portions of the Reserve, and
- 3) Public Education and Volunteer Support to provide educational and work opportunities for schools and other concerned groups.

A six-year implementation schedule is proposed. An annual budget of \$200,000 will be needed to manage the Reserve over this time period. Once feral pigs are controlled, annual management costs should decrease. Considerable benefit and monetary savings can be accrued to both the NARS and Hawaii Volcanoes National Park by participating in joint management activities.

---

HAWAII NATURAL AREA RESERVES SYSTEM  
DEPARTMENT OF LAND AND NATURAL RESOURCES  
PUU MAKAAALA NATURAL AREA RESERVE MANAGEMENT PLAN

---

I. INTRODUCTION

In 1970, Hawaii became one of the first states in the country to recognize the importance of its unique natural resources by establishing the State Natural Area Reserves System (NARS). The NARS is legally mandated to "preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawaii" (HRS 195-1). To date, there are 18 reserves on 5 islands, occupying more than 108,000 acres of the state's most biologically diverse ecosystems.

Governor Waihee and the 1987 Legislature appropriated substantial new funding and legislative mandates to develop and implement a management program in the NARS. Directives were given to write comprehensive management plans for each reserve, based on the most current and relevant biological information available.

This plan describes the NARS management program proposed for the Puu Makaala Natural Area Reserve, established in 1981 by Executive Order 3102. It consists of five parts:

- o a brief **Introduction** to acquaint the reader with the project and how the plan was prepared;
- o a **Resources Summary** describing the natural resources within the reserve;
- o a **Management Plan** describing programs recommended to maintain the reserve's resources with an analysis of alternative actions and impacts;
- o a **Budget Summary** listing the funds necessary to carry out the management plan; and
- o **Appendices** describing resource information in more detail.

Three major sources of information were used to prepare this plan. The first was The Nature Conservancy's Hawaii Heritage database on unique natural communities and rare species. The second was a field inventory conducted in February 1988, specifically designed to collect data relevant to this plan. The third was a review of this plan by qualified managers, planners, and biologists familiar with the area and its problems.

Ground survey crews spent 11 days collecting data on natural communities, rare plants, native birds, feral ungulates, and non-native weeds. Helicopter reconnaissance was used to provide information on the reserve's remote sections. Ten survey transects (Figure 1), ranging from 2,300 - 7,700 feet in length, and three supplemental stations, sampled the range of vegetation units as described by J.D. Jacobi (1983) in the reserve at 165-foot intervals along the transects (appendices 1-2).

The survey was designed to gather management-oriented resource information over a large area in a short time period and was not intended to be a comprehensive biological inventory. Sampling of small mammals, birds, and invertebrates was incidental rather than systematic. Detailed survey methods are available upon request. Lists of plant and bird species currently known from the reserve are in Appendices 3 and 4.

This plan is intended to establish long-range goals and priorities of management at Puu Makaala NAR, and to describe specific programs and activities to be accomplished during the upcoming 1989-1991 biennium. This plan will be updated biannually to incorporate new knowledge and refine management concepts.

## II. RESOURCES SUMMARY

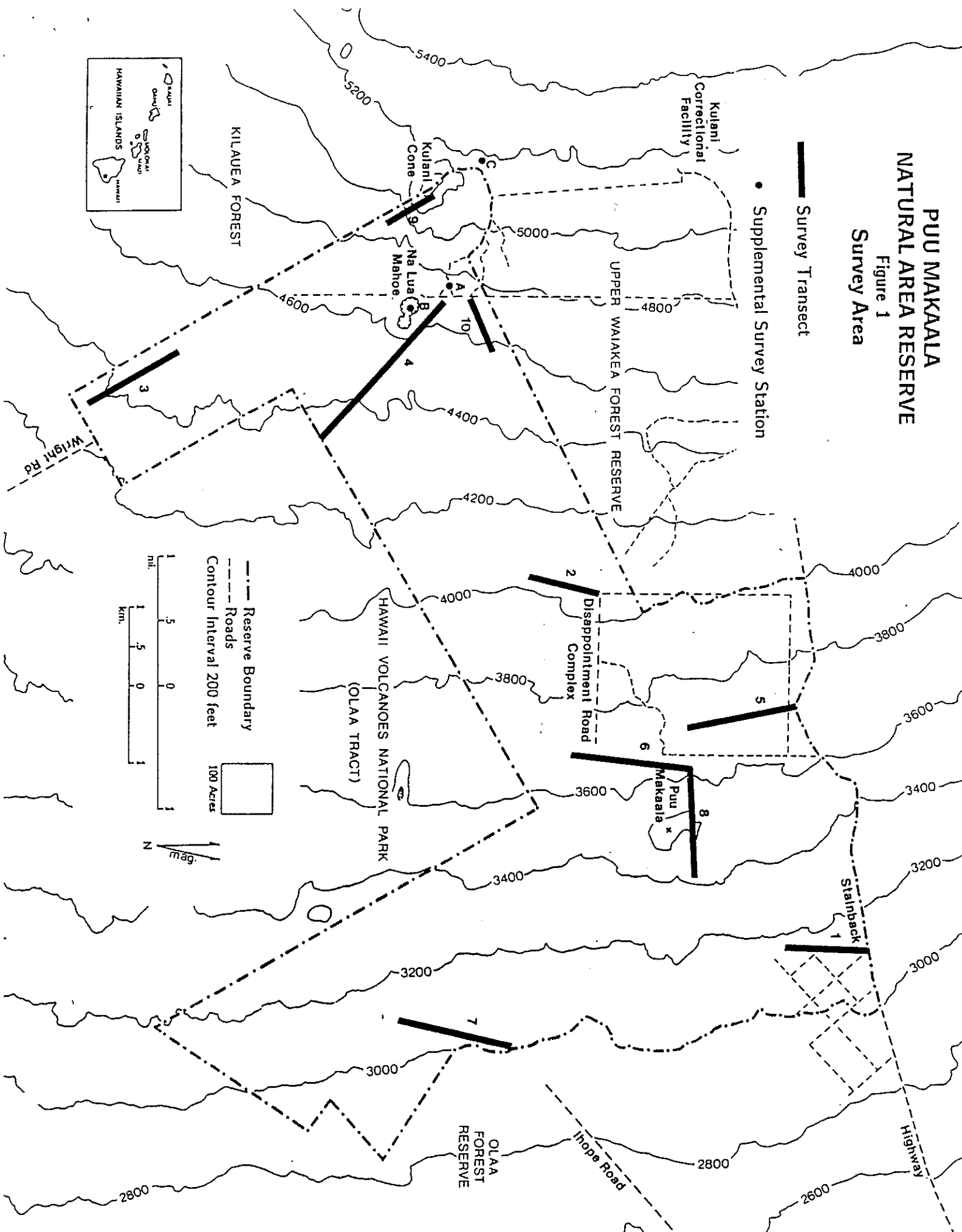
### A. General Setting

Puu Makaala Natural Area Reserve occupies 12,106 acres in the Puna and South Hilo districts on the island of Hawaii. Elevations range from 2,800 - 5,500 feet and the average annual rainfall is 100-175 inches (DLNR 1986). Landmarks include Kulani Cone and Puu Makaala (Figure 1). The reserve is bordered by the Upper Waiakea Forest Reserve on the north, the Kilauea Forest on the west, Olaa Forest Reserve on the east, and the Olaa Tract of Hawaii Volcanoes Park (HAVO) on the south. Kulani Correctional Facility lies just outside the reserve's northwest corner. Access to portions of the reserve is generally good via Wright Road and jeep trails, although public access to the reserve northern boundary via Stainback Highway is restricted by regulations of the correctional facility.

Regionally, the Puu Makaala reserve represents an important conservation parcel. It provides a link between the lower elevation HAVO Olaa Tract and the higher elevation 'ohi'a (Metrosideros polymorpha)/koa (Acacia koa) forests of Kilauea, Kulani and Upper Waiakea, protecting the transition between the 'ohi'a and koa forest types. These forest areas contain a full mosaic of different-aged 'ohi'a stands.

# PUU MAKALA NATURAL AREA RESERVE

Figure 1  
Survey Area



## B. Flora

Puu Makaala reserve encompasses some of the Big Island's best wet native forest. Four natural communities occur in the reserve; three are dominated by native species (Table 1).

TABLE 1  
NATURAL COMMUNITIES IN THE PUU MAKAAALA NATURAL AREA RESERVE

Community Name	HHP Rank <sup>1</sup>
<u>Carex alligata</u> Montane Wet Grassland	3
Koa/'Ohi'a ( <u>Acacia koa</u> / <u>Metrosideros polymorpha</u> ) Montane Wet Forest	3
'Ohi'a/Hapu'u ( <u>Metrosideros polymorpha</u> / <u>Cibotium</u> spp.) Montane Wet Forest	3
Tropical Ash ( <u>Fraxinus uhdei</u> ) Plantation	X

- <sup>1</sup> Key to Hawaiian Heritage Program Ranks:  
3 restricted range (typically more than 20 occurrences globally)  
X non-native community

'Ohi'a/Hapu'u (Cibotium spp.) Montane Wet Forest (Figure 2) occupied the majority (11,200 acres or 92%) of the Puu Makaala reserve, meeting with the koa/'ohi'a forest near the western reserve's boundary, and extending east of the reserve. A variety of substrate types, including cinder, 'a'a and pahoehoe flows of variable age, result in a mosaic of different-age stands of 'ohi'a/hapu'u forest. The closed 'ohi'a canopies can exceed 75 feet in height. Other sections of the 'ohi'a/hapu'u forest were in various stages of dieback, ranging from a few senescent trees to sections where all trees are dead and fallen, with only a few snags standing over a 15 to 30 foot canopy dominated by hapu'u and an association of native trees.





The hapu'u, or treefern layer in this 'ohi'a/hapu'u wet forest is dominated by Cibotium glaucum, but C. chamissoi and C. hawaiienses can be locally abundant (Plate 1). The native tree association below the 'ohi'a canopy commonly included 'olapa (Cheirodendron trigynum), kawa'u (Ilex anomala), pilo (Coprosma spp.), kolea (Myrsine lessertiana), smaller stature 'ohi'a, and occasionally included na'io (Myoporum sandwicense), manono (Hedyotis affinis), loulu (Pritchardia beccariana) and 'ohe (Tetraplasandra spp.). The vegetation under the hapu'u layer consisted of a mix of native ferns such as Thelypteris sandwicensis, ho'i'o (Athyrium sandwichianum), 'ama'u (Sadleria spp.) and Dryopteris spp.; native shrubs such as pu'ahanui (Broussaisia arguta), 'ohawai (Clermontia spp.), ha'i'wale or kanawao ke'oke'o (Cyrtandra spp.), Cyanea spp.,

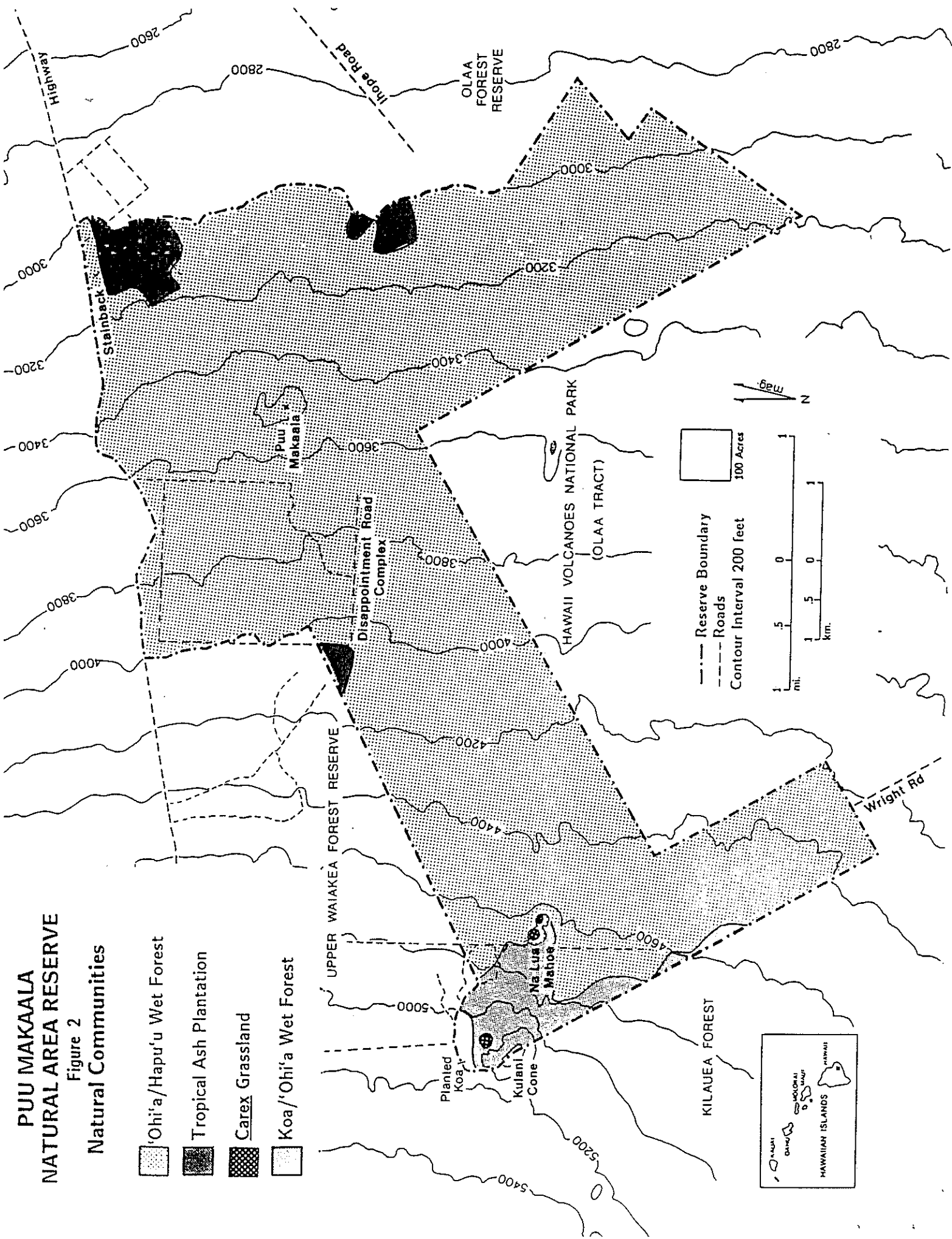




# PUU MAKAALA NATURAL AREA RESERVE

Figure 2  
Natural Communities

-  'Ohi'a/Hapu'u Wet Forest
-  Tropical Ash Plantation
-  Carex Grassland
-  Koa/'Ohi'a Wet Forest





maile (Alyxia oliviformis), alani (Pelea spp.), and 'ohelo (Vaccinium spp.); seedlings of 'olapa, 'ohi'a, kawa'u, kolea and pilo; and herbs such as pa'iniu (Astelia menziesiana) and 'ala'alawainui (Peperomia spp.). Sedges such as Carex alligata and Uncinia uncinata were infrequent components of the ground cover. Epiphytic mosses, ferns, herbs and shrubs were present, and occasionally abundant.

Koa/'Ohi'a Montane Wet Forest occupied the northwestern edge of the Puu Makaala reserve on cinder and ash substrate. This community encompasses just 460 acres or 3.8 percent of the reserve. The forest type stretched into the reserve's Kulani Cone area from the adjacent Kilauea Forest. Scattered individual koa trees, from 60 to 120 feet in height, emerge from a layer of 'ohi'a 30 to 90 feet in height. Under the koa and 'ohi'a canopy is an association of native trees that commonly included kolea, kawa'u, 'olapa, pilo and young 'ohi'a, but may also include naio and 'ohe.

The 'ohi'a/hapu'u and koa/'ohi'a wet forests share many of the same component species. The former, however, had an overall higher diversity by virtue of the greater area and elevational range it occupies. Some genera in Puu Makaala, such as Pritchardia, Trematolobelia, and Claoxylon, as well as species such as anini (Eurya sandwicensis) and Cyanea tritomantha, seem restricted to the 'ohi'a/hapu'u forest.

Carex Alligata Montane Wet Grasslands are scattered throughout the reserve as small but distinct patches occupying low lying water-saturated areas such as cinder cone pits or depressions in the forest. Only a few of the Carex grasslands were encountered on the ground survey but many examples were seen during helicopter reconnaissance. This grassland may consist entirely of Carex but may also include scattered shrubs of 'ohi'a and patches of wawae'iole (Lycopodium spp.), especially in ecotones with surrounding forest. Often associated with standing water, this sedge forms a wide margin around a pond. As the pond ages, the basin may become dominated by Carex. The largest examples occupy cinder cone craters on Kulani and Na Lua Mahoe.

Along the eastern boundary, 360 acres of tropical ash (Fraxinus uhdei) plantations constitute the reserve's only non-native dominated community. Amidst the scattered ash trees are elements of the surrounding 'ohi'a/hapu'u forest, as well as a variety of non-native plants. At this time, the ash is not invading adjacent native forest in the reserve. There were many non-native plants found within these four natural communities. The priority weeds are discussed in the Non-native Plant Control program. Appendix 3 has a full species list of all non-native plants found in the Reserve.

Of the 28 rare plant taxa reported from the Puu Makaala area, nine have been verified within the reserve's boundary (Table 2, Figure 3). Nine other rare taxa may well occur in the Puu Makaala reserve; all are known from adjacent areas. Ten additional rare taxa reported in literature might be found in the reserve upon further survey, however, location information was not specific enough to include in this discussion, though they are listed in Appendix 3.

For the purposes of this management plan, a species or natural community is considered rare if it is known from 20 or fewer locations worldwide, or less than 3,000 individuals. Due to changes in taxonomy, some taxa currently listed as candidate species in the most recent Federal Register may no longer be considered rare by the Hawaii Heritage Program, and their federal status is being reevaluated (Herbst 1988).

None of the nine rare plant taxa reported to occur in the Puu Makaala reserve is officially listed as endangered or threatened by the U.S. Fish and Wildlife Service (1985), however, there are several candidates. Three taxa are candidates under taxonomic treatment used by USFWS (1985), and their federal status is being reevaluated (Herbst pers. comm.): anini (Eurya sandwicensis), Phyllostegia floribunda, and P. velutina. Three other taxa have maintained their taxonomic treatment in Wagner et al. (in press); 'ohawai (Cyanea tritomantha), ha'iwale (Cyrtandra giffardii), and ma'ohi'ohi (Stenogyne macrantha), and are also candidates in the 1985 Federal Register. The remaining three rare taxa, Asplenium schizophyllum, 'ohe (Joinvillea ascendens ssp. ascendens) and 'anunu (Sicyos alba), have not been accorded any federal status, but are considered rare by the Hawaii Heritage Program. Two of these taxa, Asplenium schizophyllum and Joinvillea ascendens ssp. ascendens, have not been reported since the 1960's.

Six of the seven rare plant taxa confirmed within the reserve boundary recently (since 1972) were seen during the survey (Table 2). Anini (Eurya sandwicensis) was observed on transect 5 near Stainback Highway. Anini is considered very rare on the Big Island, where recently it has been reported only from the Puu Makaala area. A thriving colony of 'ohawai (Cyanea tritomantha) with seedlings was observed west of Puu Makaala in the Disappointment Road area; another was seen off Stainback Highway near the reserve's northeastern corner. 'Anunu (Sicyos alba), found on transect 6, is a recently discovered species known only from in or near the Puu Makaala reserve.

Phyllostegia floribunda which is a rare mint endemic to the Big Island was seen in the reserve near the Disappointment Road complex. Another mint, Phyllostegia velutina, was observed at Kulani Cone, and is known from only the Kulani area of the reserve and the Kilauea Forest/Keahou Ranch area. A population of about 30 ma'ohi'ohi (Stenogyne macrantha), some climbing to a height of 8 feet, was seen in the reserve's southwestern leg on transect 3.

Nine other rare taxa have been found near, but not in, the Puu Makaala reserve: Adenophorus periens, two species of 'oha (Clermontia lindseyana and C. peleana), two species of 'ohawai (Cyanea giffardii and C. stictophylla), alani (Pelea zahlbruckneri), Phyllostegia racemosa, ma'ohi'ohi (Stenogyne scrophularioides), and the endangered Hawaiian vetch (Vicia menziesii).

TABLE 2  
RARE PLANTS IN THE PUU MAKAAALA NATURAL AREA RESERVE

Scientific Name <sup>1</sup> Former Name <sup>2</sup> (Common Name)	Current (Historic) Occurrences <sup>3</sup> in Reserve	Federal Status <sup>4</sup>	Rank <sup>5</sup> HHP
<u>Asplenium schizophyllum</u> ( - )	0(1)	-	1
* <u>Cyanea tritomantha</u> (`ohawai, `oha, haha)	2(0)	C1	2
<u>Cyrtandra giffardii</u> (ha`iwale, kanawao ke`oke`o)	2(0)	C2	1
* <u>Eurya sandwicensis</u> <u>E. sandwicensis</u> var. <u>grandifolia</u> (anini)	2(0)	-	2
<u>Joinvillea ascendens</u> ssp. <u>ascendens</u> (`ohe)	0(2)	-	1
* <u>Phyllostegia floribunda</u> <u>P. floribunda</u> var. <u>forbesii</u> ( - )	2(0)	- C1	1
* <u>Phyllostegia velutina</u> <u>P. macrophylla</u> var. <u>velutina</u> ( - )	1(0)	- C1	?
* <u>Sicyos alba</u> (`anunu)	1(0)	-	1
* <u>Stenogyne macrantha</u> (ma`ohi`ohi)	1(0)	C1	1

\* Observed during 1988 survey.

<sup>1</sup> Wagner and Wagner (unpublished)

<sup>2</sup> Wagner et al. (in press)

<sup>3</sup> Following taxonomy used in USFW Federal Register (1985)

<sup>4</sup> Current occurrences reported since 1972

<sup>5</sup> Key to Federal Status (1985 Federal Register):

C1 Candidate for endangered or threatened status.

C2 Candidate for endangered or threatened status, information lacking.

- No federal status.

<sup>5</sup> Key to Hawaii Heritage Program Ranks (more than 1 dictates a range)

1 Critically imperilled globally (typically 1-5 known occurrences).

2 Imperilled globally (typically 6-20 occurrences)

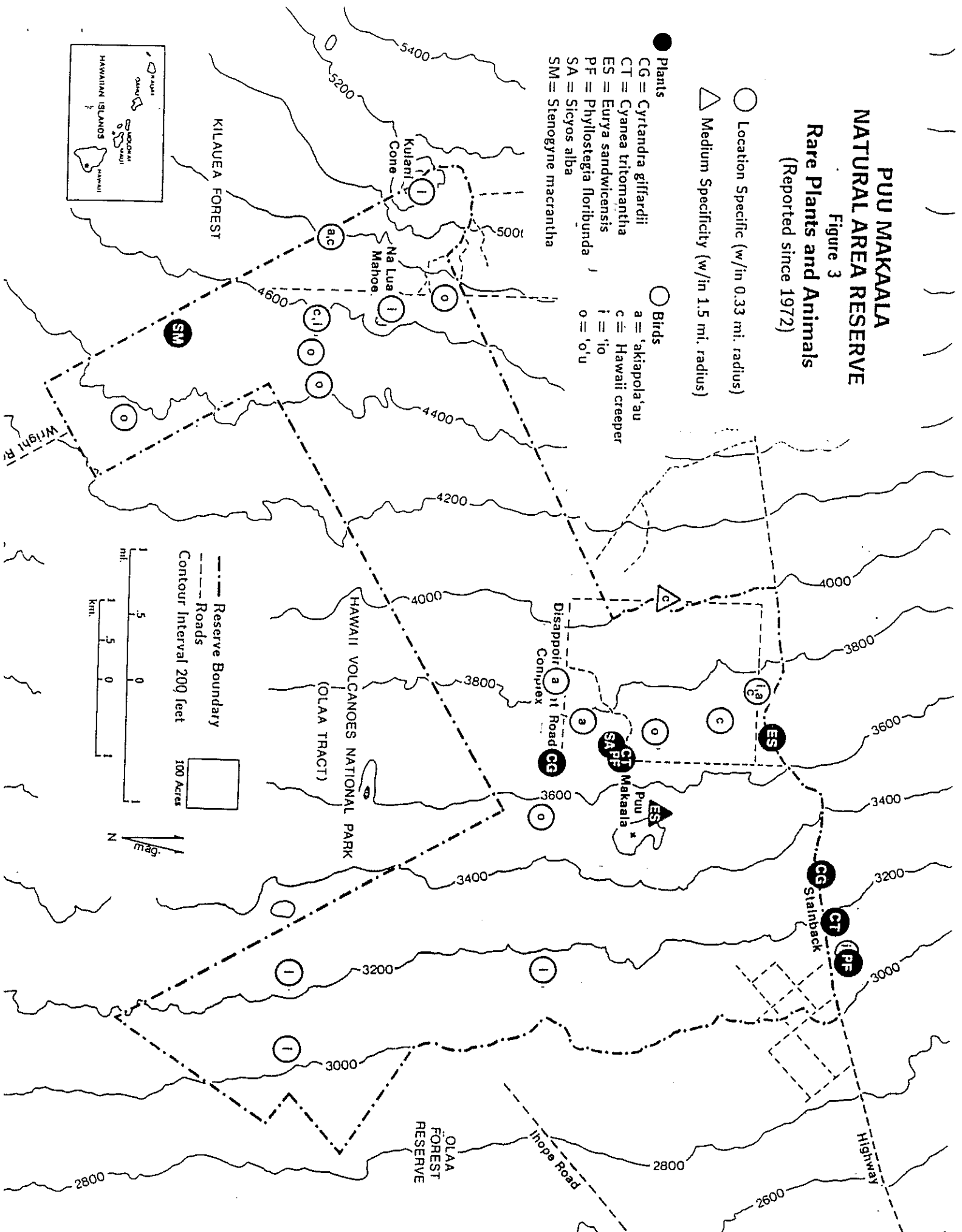
? No more than 100 occurrences globally; rank not yet determined by HHP.

# PUU MAKALA NATURAL AREA RESERVE

Figure 3  
Rare Plants and Animals  
(Reported since 1972)

○ Location Specific (w/in 0.33 mi. radius)  
△ Medium Specificity (w/in 1.5 mi. radius)

- Plants
- CG = *Cyrtandra giffardii*
  - CT = *Cyanea tritomantha*
  - ES = *Eurya sandwicensis*
  - PF = *Phyllostegia floribunda*
  - SA = *Sicyos alba*
  - SM = *Stenogyne macrantha*
- Birds
- a = 'akiapola'au
  - c = Hawaii creeper
  - i = 'io
  - o = 'o'u



--- Reserve Boundary  
--- Roads  
--- Contour Interval 200 feet  
100 Acres

1 5 0 0 1  
mi.  
1 5 0 0 1  
km.

N  
mag.

## C. Fauna

Systematic circular plots were used to sample birds along transects 4 and 6; and incidental bird observations were made on all other transects. Only two native birds were commonly seen in the reserve during this survey. The Apapane (Himatione sanguinea) was abundant throughout, except in areas of extensive 'ohi'a dieback. The Hawaiian Thrush, or 'Oma'o, (Myadestes obscurus) was less abundant, but ubiquitous, being recorded on nearly all stations.

Two other native forest birds, 'I'iwi (Vestiaria coccinea) and 'Elepaio (Chasiempis sandwichensis ridgewayi) were uncommon. The non-native Japanese White-eye (Zosterops japonicus) occurred in low numbers at most stations, whereas Redbilled Leiothrix (Leiothrix lutea) were heard at only a few stations. These findings are similar to those of previous surveys except that densities of 'I'iwi, 'Elepaio, White-eye, and Leiothrix were lower (Pratt 1988).

Four endangered bird species have been reported from the Puu Makaala reserve (Table 3, Figure 3 and Appendix 4), but only one, the 'Io (Buteo solitarius, Hawaiian Hawk), was seen during the survey. An 'Io was seen carrying nesting materials near Na Lua Mahoe, and another was seen during transect 6.

The 'O'u (Psittirostra psittacea) is extremely rare and localized on the Big Island and Kauai. Olaa Tract and kipukas of Upper Waiakea Forest Reserve, above Stainback Highway are thought to be primary habitat for 'O'u on the Big Island. 'O'u were last seen in the southwestern portion of the reserve in 1986.

TABLE 3  
RARE BIRDS IN THE PUU MAKALA NATURAL AREA RESERVE

Scientific Name (Common Name)	Estimated Pop. on the Big Is. <sup>1</sup>	Federal Status <sup>2</sup>	HHP Rank <sup>3</sup>
* <u>Buteo solitarius</u> ( 'Io, Hawaiian Hawk)	1,400 - 2,500	LE	2
<u>Hemignathus munroi</u> ( 'Akiapola'au)	1,500 $\pm$ 400	LE	2
<u>Oreomystis mana</u> (Hawaii Creeper)	12,500 $\pm$ 2,000	LE	3
<u>Psittirostra psittacea</u> ( 'O'u)	400 $\pm$ 300	LE	1

\* Observed during 1988 survey.

<sup>1</sup> Birds/km<sup>2</sup> with a 95% confidence interval. All estimates from Scott et al. 1986, except 'Io (USFWS 1984).

<sup>2</sup> Key to Federal Status (USFWS 1987):

LE Endangered.

<sup>3</sup> Key to Hawaii Heritage Program Ranks:

1 Critically imperilled globally (fewer than 1,000 individuals).

2 Imperilled globally (1,000-3,000 individuals).

3 Restricted range (typically 3,000-10,000 individuals).

`Akiapola`au (Hemignathus munroi) exist only on the Big Island, with the largest population on the windward side (Scott et al. 1986). Generally observed in koa/`ohi`a forests in this area, `Akiapola`au sightings are reported from west of the reserve in the Kilauea Forest, and north of Kulani Cone. Observed periodically in the reserve's Disappointment Road area, one record also exists from the western edge of the reserve below Kulani Cone.

Hawaii Creeper (Oreomystis mana), known from the Big Island's Kona, Kau and windward areas, is one of Hawaii's more abundant endangered forest birds. Creepers have been reported from the reserve's Disappointment Road complex, and the western area near Kulani Cone and Na Lua Mahoe, as well as south in Olaa Tract, and west of the reserve near Puu Lalaau.

Hawaii `Akepa (Loxops coccineus) is an uncommon bird on the Big Island. On the windward side, populations are known from the upper slopes of Mauna Kea and Mauna Loa, preferring closed canopy koa/`ohi`a forests (USFWS 1982). Though `Akepa have not been reported within the reserve, sightings of this rare bird are recorded from outside the reserve's western boundary in the Kilauea Forest as recently as 1987.

Although native invertebrates were only incidentally noted, a high diversity of representative native insects, spiders and snails (particularly Succinea spp.) was observed in all of the natural communities sampled and on all transects. The general richness of native invertebrates suggests that the native communities of the reserve are generally intact, and that major disruptive factors, such as competition with non-native species, have not greatly affected the native invertebrate biota. A lava tube was found and further study may reveal native cave invertebrates of interest.

Non-native fauna such as pigs (Sus scrofa) were seen throughout the Reserve and are specifically discussed in the Ungulate Control program. Other non-native mammals, such as rats (Rattus spp.) and mongoose (Herpestes auropunctatus) have been reported in the Reserve.

### III. MANAGEMENT

#### A. Key Management Concerns

The overall management goal is to protect and maintain the reserve's native character. Some of the key considerations behind the management programs proposed to achieve this are as follows:

- (1) Puu Makaala is a very large reserve. At this time it is not economically realistic to intensively manage the entire reserve. Intensive management of key areas are proposed and prioritized based on the biological resources they contain, the extent of current disturbance, the nature of the other biological threats within and near the area, and the feasibility of management (e.g. topography and access).

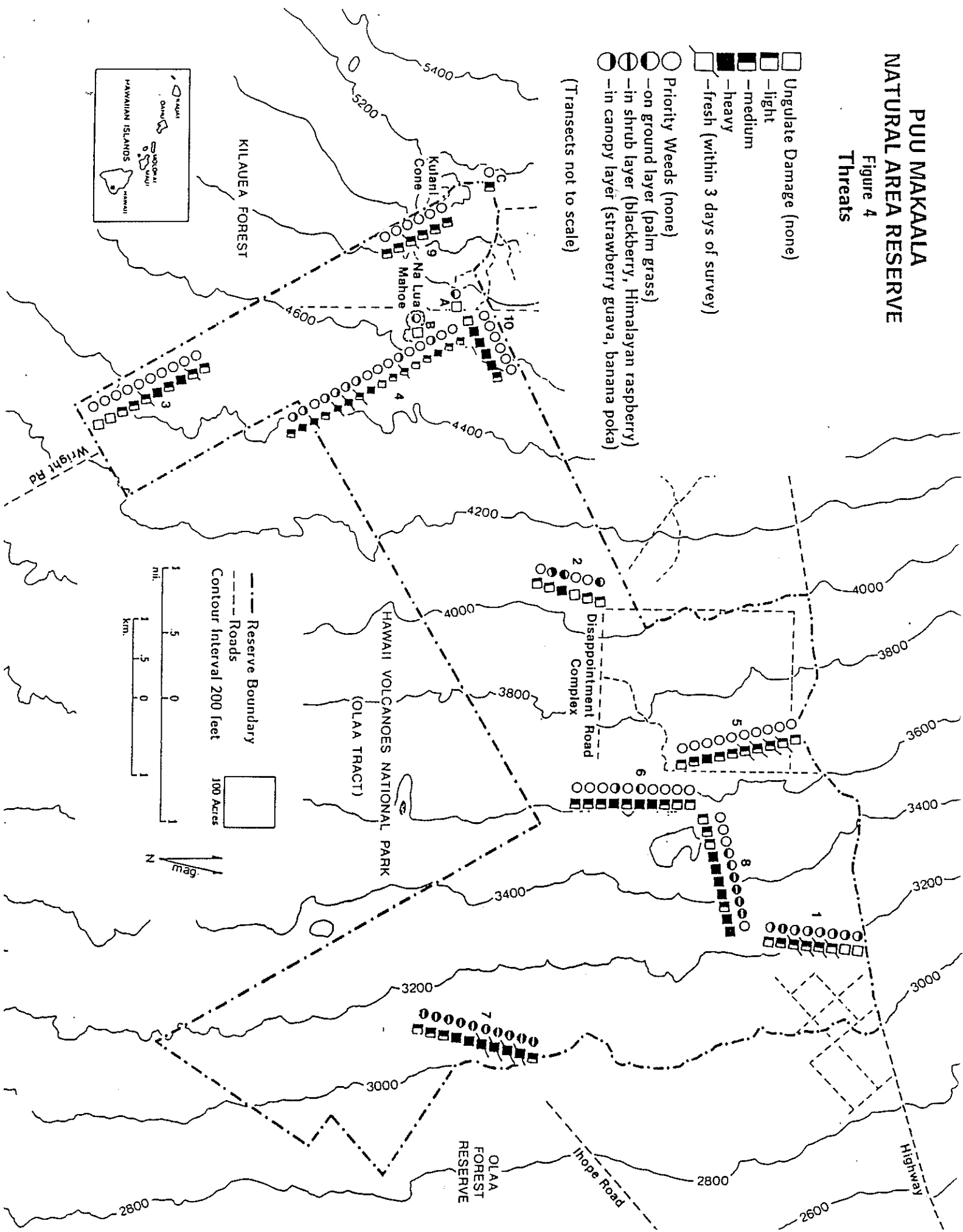


# PUU MAKALA NATURAL AREA RESERVE

Figure 4  
Threats

- Ungulate Damage (none)
- ◻ —light
- ◻ —medium
- ◻ —heavy
- ◻ —fresh (within 3 days of survey)
- Priority Weeds (none)
- —on ground layer (palm grass)
- —in shrub layer (blackberry, Himalayan raspberry)
- —in canopy layer (strawberry guava, banana poka)

(Transects not to scale)



- (2) Pigs constitute the most severe threat currently affecting the reserve (Figure 4). Their rooting and wallowing destroy native plants and the ground cover on the forest floor (Plate 2). Such damage limits effective regeneration of native plants, and creates conditions favorable for mosquitos and certain non-native weeds throughout the reserve. This in turn degrades the quality and integrity of native plant communities, threatening the existence of species that rely on the forest for survival.

Control of the feral pig population is the essential first step in the restoration and maintenance of native plant communities in the reserve. Strategic fencing to create smaller pig control units and an aggressive ungulate control program are critical for effective long term reduction of the pig population.

Portions of the reserve are utilized for recreational hunting, which should continue to be encouraged year round. This helps reduce pig densities in certain areas. However, as the number of pigs decrease in priority management areas, public hunting becomes less effective as hunters move to areas with more chance of success, and pig control by staff will be necessary. If incentives can be developed for public hunters to continue to hunt in areas where pig numbers are low, then expensive fence construction and staff hunting may not be necessary.

- (3) `Ohi`a dieback continues to have an impact in the reserve, especially in the lower elevations. Dieback is a natural successional phenomenon in which older stands die synchronously, leaving gaps in the forest canopy. Dieback itself is not a "threat" as these gaps provide openings for subsequent `ohi`a regeneration. The management concern in the dieback areas is the invasion of aggressive non-native weeds, accelerated by feral pigs, which hampers native plant regeneration. Aerial photographs indicate over one-third of the `ohi`a forests in the reserve have undergone relatively recent dieback.
- (4) Many non-native plants observed in the reserve are shade intolerant and pose no major problem as long as the native canopy and ground cover remain intact. There are non-native weed species in the reserve which form monotypic stands and displace native vegetation over large areas, making them priority weeds for management. Weed control activities will focus on these invasive weeds within key management areas, and in localized populations of priority weed species. Biological control efforts for widespread weed species should be supported.
- (5) Signs of marijuana cultivation were seen in the reserve. This illegal activity creates a hazard for people in the reserve. Growers destroy native plants clearing patches for cultivation, introducing new weeds to the forest and spreading others.



## B. Management Zone Descriptions

The reserve has been divided into five management zones, two of which are subdivided into smaller management units (Figure 5). Descriptions of each zone/unit spell out key features, problems, and priorities for management.

### Disappointment Road Zone (3,060 acres)

Lower Disappointment Road Unit - This unit is 1,100 acres of closed and open canopy `ohi`a/hapu`u forest with some dieback. The forest is intact with diverse native vegetation, rare plants and birds. It has little weed invasion, light pig impact, and excellent public access. This is the highest priority area for pig and weed control.

Stainback Unit - This unit is 560 acres of closed and open `ohi`a/hapu`u forest. The forest is intact with diverse native vegetation and rare plants. It has little weed invasion, light pig impact, and excellent access. This is the highest priority area for pig and weed control.

Upper Disappointment Road Unit - This unit is 300 acres of closed and open `ohi`a/hapu`u forest with little dieback. The forest is relatively intact with diverse native vegetation. This unit is smaller because of road access and is a source area for palm grass invasion. It is a high priority area for pig and weed control.

Olaa Unit - This unit is 570 acres of closed and open `ohi`a/hapu`u forest with some dieback. There is moderate pig impact. This is a source area for banana poka and palm grass. It abuts HAVO Olaa Tract and access is poor. This is a medium priority unit for pig and weed control.

Puu Makaala Unit - This unit is 530 acres of open `ohi`a/hapu`u forest with moderate dieback and medium to heavy pig impact. Unit is a source area for palm grass and strawberry guava. Puu Makaala is a geologic feature with public education value. Access is good. This is a medium priority unit for pig and weed control.

### Kulani Cone Zone (1,440 acres)

Kulani Cone Unit - This unit is 590 acres of closed and open koa/`ohi`a/hapu`u forest. The forest is intact with little weed invasion, medium pig impact, and supports rare birds. It contains the best koa forest in the reserve. It is easily accessible for management work. This unit has the highest priority for pig and weed control.

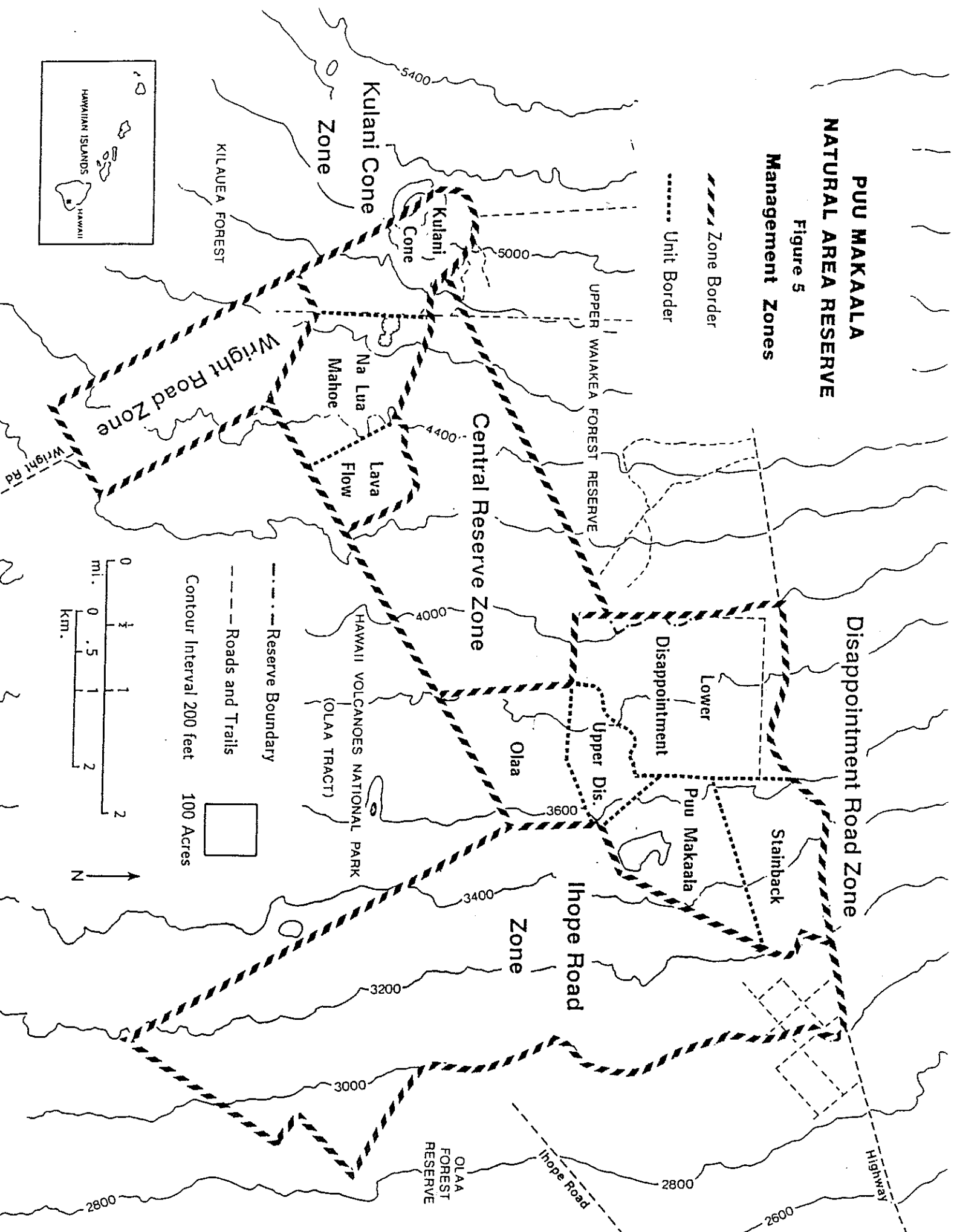
Na Lua Mahoe Unit - The unit is 550 acres of mostly `ohi`a/hapu`u forest with some koa. The forest is intact with light weed and variable pig impact. It is important regionally as bird habitat and a corridor to the HAVO Olaa Tract. Access for management personnel is good. This unit has the highest priority for pig and weed control.

Lava Flow Unit - The unit is 300 acres of open `ohi`a/hapu`u forest with dieback. The forest is relatively intact but pig and weed impacts are moderate. This is source area for banana poka. The unit abuts the HAVO Olaa tract. This unit has a high priority for pig and weed control.

# **PUU MAKALA NATURAL AREA RESERVE**

Figure 5

## **Management Zones**



#### Wright Road Zone (940 acres)

This zone has no sub-units and consists of open `ohi`a/hapu`u forest. The forest is intact and has little weed invasion and medium pig impact. Rare plants and birds are present. Public access is excellent. The unit is an important corridor between the HAVO Olaa tract and the Kilauea Forest. At this time, the unit has a low priority for active management. Regular monitoring will assess public hunting success in keeping pig populations down. While the heavy treefern cover keeps out shade-intolerant weeds, shade-tolerant weeds and banana poka should be watched for. This zone has the highest priority for monitoring.

#### Central Reserve Zone (2,030 acres)

This single-unit zone has closed to open `ohi`a/hapu`u forest. The forest closer to Stainback Highway is more intact with less pig and weed impacts. Closer to the HAVO boundary, the forest opens up with some dieback and increased weed and pig impact. Banana poka infestation near the HAVO Olaa Tract is a problem. At this time, the unit has a low priority for active management because of poor access and other priorities within the reserve. This zone is a valuable corridor between the Kulani Cone and Disappointment Road management zones and should be regularly monitored. This zone has the highest priority for future survey work.

#### Ihope Road Zone (4,640 acres)

Open to scattered `ohi`a/hapu`u with extreme dieback and weeds, especially palm grass and strawberry guava, dominate large sections of this zone. Pig impact is moderate to heavy. Public access is good via Ihope Road. At this time, the unit has a low priority for management, but it is important as it provides a buffer zone for the reserve and encompasses older `ohi`a stands undergoing regeneration.

### C. Management Programs

The following four management programs outline the long-term goals for the reserve. The management activities within each program lay essential foundations for effective protection of the reserve's natural resources. A six-year implementation schedule is recommended. Although the programs are listed by priority, they fit together to form an integrated management package.

#### Ungulate Control Program (PUM-RM-01) - Priority #1

GOAL: Reduce impact of pigs to a level that prevents further degradation of the reserve's native species and allows the greatest possible recovery of the reserve's native character.

Statement of the Problem: Techniques available for pig control in the reserve include hunting with or without dogs, snaring, baiting and trapping. Current pig control research recommends use of passive control (e.g. snares and traps) before actively controlling with dogs when possible, unless hunting is already established. There is less investment initially, less upkeep, less chance of the program being overly oriented to hunting, and it is more cost effective in remote areas. Hunting can be alternated with snaring, but snares must be

removed from areas prior to hunting to avoid catching dogs. Radio transmitters on lead hunting dogs has improved hunting efficiency and trapping can be useful for the first vulnerable animals in an area.

Reduction is the necessary first phase of a control effort. Long-term funding for fence construction, pig control and fence maintenance are needed. Attempts to reduce pig populations to remnant levels in similar terrain without the use of any fences have not been effective due to unimpeded ingress of animals into areas where population densities were reduced. Funds spent on feral pig control will be ineffective unless pig numbers are reduced to remnant populations and not allowed to build back up to damaging levels.

#### Alternative Actions and Probable Impacts:

- 1) No action. Accept the continuing deterioration of Puu Makaala's native resources. Pigs destroy native plants, alter the structure of native vegetation, and contribute to the spread of non-native plants. Without control, pigs can be expected to degrade native communities, converting most of the reserve to less diverse assemblages of native plants with non-native weeds.
- 2) Attempt control of feral animals without installation of any fences. Damaging impacts of feral pigs under this alternative will probably be roughly the same as alternative #1, except for portions of the reserve where increased hunting activity may protect small areas of forest. Management resources used for control will be less effective without any fences to keep new pig populations from moving into the reserve.
- 3) Control feral pigs with the aid of fences. This method has proven successful in both HAVO and Haleakala National Park. Initial cost is high, but benefits in preservation of native ecosystems are great. Recovery of native vegetation can occur if feral animals are controlled. The advance of non-native weed species can be slowed and at times reversed. Native plant species surviving only as epiphytes because of feral pig disturbance can become reestablished on the forest floor.

Recommended Action: Alternative #3 is recommended. The two large management zones proposed for intensive pig control and fencing in this plan comprise only one-third of the reserve. Public hunting access is essential and encouraged to control pig populations in the rest of the reserve. However, the goal for the Disappointment Road and Kulani Cone Zones is clearly reduction of the pig population to remnant levels, not sustained yield hunting. Three projects are proposed to carry out this alternative:

Project (1) - Construction of a strategic network of 20.3 miles of barrier fences to create five management zones. Goals of the fencing project are to cut off pig access routes into priority areas and to direct predictable pig movements within intensive control areas. An aggressive snaring and hunting project is essential in conjunction with the fencing project to take advantage of induced pig movements and to avoid creation of "pig pens".

Although there are eight smaller management units within the Disappointment Road and Kulani Cone Zones, they will not be fenced immediately. A progressive fencing strategy will be used. The outside of the management zones will be fenced before individual management units are closed off. This will allow pig control efforts to begin over a larger area. In addition, success of pig control efforts and monitoring of subsequent vegetation recovery may determine that fences to close off the smaller management units may be unnecessary. The fence system will share 2.3 miles of HAVO fence along the Olaa Tract boundary. Cooperative agreements to share maintenance costs of this fence section will be pursued.

Pig control fences will consist of 39 inch high galvanized woven-wire supplemented along the ground surface by one strand of barbwire stretched tightly across the ground. Wovenwire and barbwire will be secured to steel posts placed no more than 10 feet apart. Concreted galvanized pipes may be required to secure the fenceline at certain corners. Helicopter transport of fencing materials will be required for remote units.

The following units are proposed for fencing over a five year period:

- Year 1 - Kulani Cone and Na Lua Mahoe Unit Boundary Fences  
A total of 5.8 miles of fenceline of which 1.5 miles are adjacent to an existing road. 3.5  
3.5
- Year 2 - Lava Flow Unit Boundary Fence  
A total of 1.9 miles of fence line. Approximately 1,440 acres within the Kulani Cone Zone will be fenced.
- Year 3 - Lower Disappointment Road and Stainback Unit Boundary Fences  
A total of 6.2 miles of fenceline, all of which are adjacent to an existing road.
- Year 4 - Puu Makaala Unit Boundary Fence  
A total of 1.9 miles of fenceline.
- Year 5 - Olaa Unit Boundary Fence  
A total of 3.6 miles of fenceline. Approximately 3,060 acres within the Disappointment Road Zone will be fenced.

COST/WORKLOAD:

Year 1 - 5.8 miles of fenceline -	\$188,000
Year 2 - 1.9 miles of fenceline -	\$ 66,500
Year 3 - 6.2 miles of fenceline -	\$155,000
Year 4 - 1.9 miles of fenceline -	\$ 66,500
Year 5 - 3.6 miles of fenceline -	\$126,000
<b>Total</b> 19.4 miles of fenceline	<b>\$602,000</b>

*Fencing costs  
estimated by  
25,000/mi along  
fence  
otherwise  
35,000/mi*



Costs are based on an estimated \$25,000 per mile for fencelines adjacent to existing roads and \$35,000 per mile for fenceline through the forest. Contracting for fence construction is recommended. Costs include materials, supplies, and labor for fenceline preparation (brushing and clearing of proposed fenceline), contractor logistics and actual construction. Strict procedures for clearing fenceline will be established to minimize disturbance. Does not include personnel costs for fenceline layout and assessment, contract preparation and monitoring. A botanist will walk the flagged fence route to search for rare plants to be avoided by the brushing crew.

Project (2) - Monthly inspection and maintenance of all fencelines (and after major storms). Inspections will be done in conjunction with other resource management activities such as monitoring and non-native plant control along fence corridors.

Cost/Workload: The following workload is projected for monthly fence inspection:

Year 1 - 5.8 miles of fenceline		
Technician 24 Person Days (PD)	Total	\$ 1,900
Year 2 - 7.6 miles of fenceline		
Technician (55 PD)		\$ 3,850
Supplies and Support		<u>2,900</u>
	Total	\$ 6,750
Year 3 - 13.9 miles of fenceline		
Technician (87 PD)		\$ 6,100
Supplies and Support		<u>6,950</u>
	Total	\$13,050
Year 4 - 15.8 miles of fenceline		
Technician (120 PD)		\$ 8,400
Supplies and Support		<u>7,900</u>
	Total	\$16,300
Year 5 and 6 - 18.0 miles of fenceline (+ 2.3 miles of shared HAVO fence)		
Technician (155 PD)		\$10,850
Supplies and Support		<u>9,000</u>
	Total	\$19,850

Costs are based on a two-person crew able to inspect and fix 3 miles of fence per day. Supplies for fence maintenance are estimated at \$500/mile year for fences over one year old. Salaries are \$70/person/day. Fences already constructed will be inspected 12 times/yr and fences being constructed during the year will be inspected 6 times/yr.

Project (3) - Initiate an active pig control program using hunting, trapping, snaring, and other methods as required in the in the Disappointment Road and Kulani Cone Zones. The goal is to reduce feral pig populations to remnant levels in 4,560 acres of the reserve. Pig control should begin before fence closure in order to chase out populations within the area.

Snares are recommended for the Kulani Cone Zone, where public access is restricted. Snare numbers will increase over time to continue to catch pigs as their densities decrease. The greatest effort is initially setting up the snare groups. These snare groups are left in place, as pigs habitually return to previously used areas. When new areas are found with fresh sign, additional snare groups are set out. Snares in rain forests last six months to a year. Accumulating data on health, sex, and age of captured pigs provides important data in the effectiveness of the snaring program.

Staff hunting is recommended rather than snaring in the Disappointment Road Zone. This will allow time to incorporate interested public hunters into the program. The major limitation with using public hunters is the lack of incentive for hunting an area when the chances of a successful hunt is low. An effective pig control program demands constant hunting pressure, even when pig populations decrease. Incentives such as improved access, contests, and logistical support for volunteer hunters will be offered to maintain public hunter pressure in the Disappointment Road Zone. Contracting out public hunters is also a possibility. If monitoring indicates vegetative recovery from these pig control efforts, snaring will not be used. The use of snares would necessitate closing the area to the public.

Cost/Workload: The following resources will be needed to conduct the pig control program:

Year 1: Snaring/trapping in Kulani Cone and Lua Mahoe Units  
Staff hunting with dogs in the Disappointment Road Zone.

<u>Personnel</u>	
Dog handler/trainer (100 PD)	\$ 7,000
Hunters (150 PD)	10,500
Snaring (61 PD)	<u>4,700</u>
	\$22,200
<u>Capital improvements</u>	
dog kennel	\$25,000
dogs	<u>3,000</u>
	\$28,000
<u>Materials and supplies</u>	
450 snares (\$5 ea.)	2,250
dog radio collars (4 at \$300 ea.)	1,200
radio receiver units (2 at \$2,000 ea.)	4,000
trap materials (10 at \$100 ea.)	1,000
firearms 4 at \$300 ea.	1,200
ammunition	<u>1,000</u>
	\$10,650
<b>Total</b>	<b>\$60,850</b>

Year 2: Snaring/trapping in Kulani Cone Zone.  
Staff hunting with dogs in Disappointment Road Zone.

<u>Personnel</u>	
Dog handler/trainer (100 PD)	\$ 7,000
Hunters (150 PD)	10,500
Snaring (78 PD)	<u>6,000</u>
	\$23,500
<u>Materials and supplies</u>	
570 snares (\$5 ea.)	2,850
dog food and vet services	\$ 3,000
ammunition	\$ 1,000
equipment repair	<u>\$ 2,000</u>
	\$ 8,850
Total	\$32,350

Year 3: Snaring/trapping in Kulani Cone Zone.  
Staff hunting with dogs in Disappointment Road Zone.

<u>Personnel</u>	
Dog handler/trainer (100 PD)	\$ 7,000
Hunters (200 PD)	14,000
Snaring (78 PD)	<u>6,000</u>
	\$27,000
<u>Materials and supplies</u>	
570 snares (\$5 ea.)	2,850
dog food and vet services	\$ 3,000
ammunition	\$ 1,000
equipment repair	<u>\$ 2,000</u>
	\$ 8,850
Total	\$35,850

Year 4 - 6 same as Year 3 Total \$35,850

Costs are based on a two-person (biologist/technician) crew able to establish 50 snares/day and check 250 snares/day. Snares will be replaced every year and inspected 12 times/year. Snaring densities will be 100 snares/250 acres within the management units. Salaries are \$85/day for a biologist and \$70/day for technician. Savings could be incurred by sharing costs of hunting dogs and associated expenses with HAVO or by emphasizing use of snares for the Disappointment Road Zone.

#### Monitoring Program (PUM-RM-02) - Priority #2

GOAL: Monitor the effectiveness of management work and track significant ecological changes through long-term scientific monitoring.

Statement of the Problem: Scientific monitoring must be established to track key non-native plant and animal species in the Reserve. Another monitoring function is to determine the effectiveness of operational management plans and techniques, so that progress can be documented and methodologies refined. Monitoring data is also needed to develop long range plans.

### Alternative Actions and Probable Impacts:

- 1) No monitoring program. This could lead to inefficient management as a result of poor understanding of the area's biological needs.
- 2) Conduct ad hoc monitoring whenever possible. This is likely to be considerably more expensive and less effective in the long run than a systematic approach.
- 3) Establish a systematic monitoring program that covers the current and potential resource management problems in the reserve at least once a year. Increase monitoring intensity for select problems as needed.

Recommended Action: Establish a systematic monitoring program that covers the current and potential resource management problems in the reserve at least once a year (Alternative #3). Monitoring is recommended in intensive pig control zones twice a year once they are fenced. Monitoring transects will be established about 1,500 feet apart. Monitoring in other management zones will be annual, with transects about 2,000 feet apart. Some transects may require a two-person monitoring crew because of logistics and safety. Annual aerial monitoring is suggested for the Ihope Zone because of its size, poor access, and lower priority for management.

### Cost/Workload:

Year 1:	Biologist (65 PD)	\$ 5,500
	Supplies and Support	<u>3,000</u>
	Total	\$ 8,500
Year 2:	Biologist (77 PD)	\$ 6,500
	Supplies and Support	<u>3,000</u>
	Total	\$ 9,500
Year 3:	Biologist (82 PD)	\$ 7,000
	Supplies and Support	<u>3,500</u>
	Total	\$10,500
Year 4:	Biologist (89 PD)	\$ 7,500
	Supplies and Support	<u>4,000</u>
	Total	\$11,500
Year 5 - 6	Same as Year 4	Total \$11,500

Salaries are \$85/day for a biologist. Helicopter costs are \$500/hr.

### Non-native Plant Control Program (PUM-RM-03) - Priority #3

GOAL: To limit the spread and, where possible, eradicate introduced plant species which are already or may become noxious weeds in the reserve.

Statement of the Problem: Many non-native plants have become naturalized in Hawaii and their total removal in the reserve is not feasible. The best strategy for control is to maintain intact native forests by limiting disturbance to existing native vegetation. While feral pig control will help in this regard, many weeds are spread by birds and people. Monitoring and control of priority weed species in key management units will be necessary. 'Ohi'a dieback compounds the problems by opening up the forest canopy which can encourage non-native plant establishment, especially in areas disturbed by feral pigs.

Strawberry guava (Psidium cattleianum) is a priority weed in the reserve's lower elevations (southeast corner), forming its densest stands near the Hawaii Volcanoes National Park Olaa Tract. Palm grass (Setaria palmaefolia) constitutes another large threat in the southeast section of the reserve. This aggressive grass moves quickly into clearings and pig-disturbed areas, especially where 'ohi'a is undergoing dieback. At its worst, palm grass forms a total ground cover in the understory. Aerial reconnaissance indicates approximately 20% of the reserve is infested with this perennial, which can reach heights of 5 feet.

Another threat comes from banana poka (Passiflora mollissima), which is currently most prevalent along the south boundary bordering Hawaii Volcanoes National Park Olaa Tract. Seeds are spread by birds and pigs and the vines climb into the overstory, shading out and smothering native plants. This weed is a serious threat in other forest areas in Hawaii.

Two other potential threats in the reserve are yellow Himalayan raspberry (Rubus ellipticus), and blackberry (Rubus argutus). These weeds can grow to a height of 15 feet and form impenetrable thorny thickets. During the survey, seedlings and a mature raspberry plant were observed along the west and northwest boundary of Olaa Tract, and scattered seedlings were noted along transect 2 in the Disappointment Road area. Blackberry was observed in the Wright Road area. There are other potential priority weeds such as Kahili ginger (Hecychium gardnerianum), clidemia (Clidemia hirta), and Firetree (Myrica Faya) that are established in surrounding forest areas.

Manual and chemical control of weeds is costly and their use should be prioritized by the nature of the weed, the value of the area it is invading, and the feasibility of control. Biocontrol is an important potential tool in the management of wide spread priority weed species and the NARS should support ongoing interagency biocontrol projects.

#### Alternative Actions and Probable Impacts:

1) Control pigs, but do not attempt to control any aggressive non-native plant species. This will reduce the spread of many pig-dispersed plant species, but will allow continued advance of plants through bird dispersal. The decrease in rooting and forest floor disturbance by feral pigs will slow down establishment of many non-native plants, but already established aggressive weeds could overwhelm large areas. Native plant regeneration in 'ohi'a dieback areas could be severely reduced by competition from invading non-native weeds.

2) Control priority non-native weed species in key management areas before they become widely established. Set up monitoring transects to locate incipient populations of other priority weed species. Management measures would include selective use of approved herbicide and manual removal with hand tools.

3) Control all non-native plants in the Reserve. This alternative would require extensive resources and is not practical.

Recommended Action: Alternative #2 is recommended. Once pig control has begun, use monitoring transects to map the distribution and abundance of priority weeds. Remove localized populations of weeds with appropriate manual, mechanical, and chemical means within the Disappointment Road, Kulani Cone, and Wright Road Zones. Utilize existing research conducted at HAVO to improve control efficiency. If pig control does not check the spread of target weed species, systematic weed control efforts will be required, necessitating increased manpower.

Non-native plant control activities in the Central Reserve and Ihope Zones will be limited to monitoring and control of target species along fenceline corridors. Other priority weeds such as Kahili ginger (Hecychium gardnerianum), clidemia (Clidemia hirta), and firetree (Myrica Faya) will be removed immediately if found within the reserve. Regular surveys of roadsides and developed areas will be made to monitor potential weed introductions.

Although research on non-native plant control is ongoing in HAVO, detailed records of the effectiveness of control methods used in the reserve should be kept. Careful monitoring and documentation of plant control efforts and results is very important. Coordination between NARS and HAVO will reduce plant control costs. Establish strict sanitary procedures to insure management personnel do not transport weed seeds into the reserve on their boots or equipment. Signs to warn the public of this threat will be posted at key locations.

Participation of volunteer groups in the weed control program can also reduce costs as well as increase public support for reserve management activities. Transportation, equipment, and training for volunteers are required. Reserve staff work hours will be adjusted so personnel are available to supervise volunteer work groups, especially on weekends. Eventually, leaders from volunteer groups can be trained to supervise their volunteer crews.

Cost/Workload:

Year 1 - Biologist (40 PD)	\$ 3,400
Technician (100 PD)	7,000
Supplies and support	<u>3,000</u>
Total	\$13,400
 Year 2 - Biologist (50 PD)	 \$ 4,300
Technician (200 PD)	14,000
Supplies and support	<u>4,000</u>
Total	\$22,300

Year 3 - Biologist (50 PD)	\$ 4,300
Technician (250 PD)	17,500
Supplies and support	4,400
Total	\$26,200
Year 4 - Biologist (50 PD)	\$ 4,300
Technician (300 PD)	21,000
Supplies and support	4,000
Total	\$29,300
Year 5 - 6 same as Year 4.	Total \$29,300

Public Education and Volunteer Program (PUM-RM-04) - Priority #4

GOAL: To build public understanding and support for the reserve in the local community. To provide educational opportunities, where appropriate, for interested groups. To provide volunteer labor to help staff in management activities.

Statement of the Problem: Most residents and visitors are unaware of Hawaii's natural heritage. Even fewer realize that this resource is being threatened. Opportunities for people to learn of and experience the reserve will develop an environmental awareness and increase public support for the NARS. The management of this reserve will be a costly and long-term effort and public support is essential. Because of its accessibility, the Puu Makaala reserve is ideally suited to do this.

Concerned volunteer groups have proven successful in natural area management activities, especially in labor intensive efforts such as weed control and trail maintenance. They tend to be extremely motivated and represent a valuable resource for the reserve manager.

Recommended Action: Inform the general public about the reserve and management activities, and utilize volunteer groups for reserve management whenever feasible. Develop a nature walk to Puu Makaala that describes the resources, threats, and ongoing management activities. Present slide shows and talks to community groups. Cooperate with existing environmental education organizations to use the reserve as an outdoor classroom. Train key volunteers to lead scheduled hikes with the general public through the reserve.

Cost/Workload:

Year 1 - Biologist (20 PD)	\$ 1,700
Support and supplies	2,000
(slide show and handouts)	Total \$ 3,700
Year 2-3 Same as year 1.	Total \$ 3,700

Year 4 - Biologist (30 PD)	\$ 2,400
Technician (90 PD)	6,300
Support and supplies	<u>4,000</u>
(nature walk to Puu Makaala w/brochure)	
Total	\$12,700
Year 5-6 Same as year 1.	
Total	\$ 3,700

#### E. Boundary Administration and Special Uses

Portions of the reserve are dominated by non-native vegetation as a result of planting initiatives by DLNR in the late '60s and early '70s. It is recommended that management of these areas be returned to the DLNR'S Division of Forestry & Wildlife to continue forest resource management activities. These areas are small (300 total acres), on the boundaries of the reserve, and are not essential to the reserve's management objectives. They do provide important access into the reserve and continued maintenance of these roads would benefit the reserve. It would benefit reserve management to have the west side fenceline of the Lower Disappointment Unit follow an existing 4-wheel drive road. This will necessitate about 10 acres of the Upper Waiakea Forest Reserve being included within this unit.

About 300 acres of koa forest, of which 50 acres are within the reserve, were selectively logged in the early '70s. An excellent stand of young koa is regenerating throughout this area, but overall native species diversity is very low. The logged area has been used for research in koa succession and growth and represents an important opportunity for long-term study. Both the Division of Forestry & Wildlife and the Institute of Pacific Islands Forestry (U.S. Forest Service) have expressed interest in continuing koa research work there in cooperation with the Kulani Correctional Facility. It is recommended the long-term koa silvicultural research be allowed to continue within the reserve.

Because the reserve boundary cuts directly across the steep western slopes of Kulani Cone, it would aid reserve management to gain permission from Bishop Estate and Kulani Correction Facility to include a portion of their land (50 and 8 acres respectively) within the reserve. This would allow a pig-resistant fence to be constructed on level ground and provide complete protection for Kulani Cone.



Puu Makaala Budget Summary

* PROGRAM	* YR 1	* YR 2	* YR 3	* YR 4	* YR 5	* YR 6
* PUM-RM-01 *						
* Proj. 1	* 188,000	66,500	155,000	66,500	126,000	---
* Proj. 2	* 1,940	6,750	13,050	16,300	19,850	19,850
* Proj. 3	* 60,850	32,350	35,850	35,850	35,850	35,850
* PUM-RM-02 *	* 8,500	9,500	10,500	11,500	11,500	11,500
* PUM-RM-03 *	* 13,400	22,300	26,200	29,300	29,300	29,300
* PUM-RM-04 *	* 3,700	3,700	3,700	12,700	3,700	3,700
* PUM-OP-01 *	* 54,000	5,000	5,000	5,000	5,000	5,000
<sup>1</sup> TOTAL(\$)	* 330,350	146,100	251,800	180,700	238,100	109,400

MANAGEMENT PROGRAMS

PUM-RM-01 - Ungulate Control  
                   Project 1 - Fence Construction  
                   Project 2 - Fence Maintenance  
                   Project 3 - Pig Control  
 PUM-RM-02 - Monitoring  
 PUM-RM-03 - Non-native Plant Control  
 PUM-RM-04 - Public Education and Volunteer Support  
 PUM-OP-01 - Operating Expenses

PERSONNEL

YR 1 -Biologist 156 WD Technician 404 WD	YR 4 -Biologist 208 WD Technician 849 WD
YR 2 -Biologist 186 WD Technician 544 WD	YR 5 -Biologist 198 WD Technician 794 WD
YR 3 -Biologist 191 WD Technician 676 WD	YR 6 -Biologist 198 WD Technician 794 WD

<sup>1</sup> Starting with year 3, a 1% inflation increase is incorporated into every yearly total.

## SOURCES CONSULTED

- Cooper, J.E. (ed.). In Press. Disease and Management of Threatened Bird Populations. ICBP Technical Publication Series. Cambridge, England.
- Department of Land and Natural Resources. 1986. Rainfall Atlas of Hawaii. Water Resources Research Center/Department of Meteorology, University of Hawaii at Manoa. State of Hawaii, DLNR, Division of Water and Land Development, Report R76. Honolulu, Hawaii.
- Hawaii Revised Statutes - State of Hawaii, Chapter 195-1, 1985
- Herbst, D.V. Personal Communications, June 1988. Endangered Species Botanist, Office of Environmental Services, U.S. Fish and Wildlife Service.
- Jacobi, J. D. 1985. (Unpublished). Vegetation Maps of the Upland Plant Communities on the Islands of Hawaii, Maui
- Pratt, T. 1988 (Unpublished). Puu Makaala Bird Survey. Report on file at DLNR.
- Scott, M. J., S. Mountainspring, F. L. Ramsey, and C. B. Kepler. 1986. Forest Bird Communities of the Hawaiian Islands: their Dynamics, Ecology, and Conservation. Studies in Avian Biology No 9, Cooper Ornithological Society. Allen Press, Lawrence, Kansas.
- U.S. Fish and Wildlife Service. 1987. Endangered and Threatened Wildlife and Plants. 50 CFR 17.11 & 17.12. U.S. Government Printing Office, Washington, D.C.
- U.S. Fish and Wildlife Service. 1985. Federal Register. 50 CFR Part 17. Vol. 50, No. 188. Department of the Interior. U.S. Government Printing Office, Washington, D.C.
- U.S. Fish and Wildlife Service. 1984. The Hawaiian Hawk Recovery Plan. Prepared under contract with Curtice R. Griffin, Missouri Cooperative Wildlife Research Unit.
- U.S. Fish and Wildlife Service. 1982. The Hawaii Forest Bird Recovery Plan. Prepared in cooperation with the Hawaii Forest Bird Recovery Team.
- Wagner, W. H. Jr. and F. S. Wagner. 1987 (Unpublished). Revised Checklist of Hawaiian Pteridophytes.
- Wagner, W. L., D. R. Herbst and S. H. Sohmer. In Press. Manual of the Flowering Plants of Hawaii. Bishop Museum Press, Honolulu, Hawaii.

#### ACKNOWLEDGEMENTS

Several organizations and individuals contributed information, guidance, and review for this management plan. Their cooperation and support is deeply appreciated. In particular, thanks to Barri Morgan, Steve Perlman, Sam Gon, Audrey Newman, and all the other hard working and dedicated professionals at the Hawaii Heritage Program of the Nature Conservancy of Hawaii who helped me prepare this plan; Division of Forestry and Wildlife staff Thane Pratt, Ron Walker, Charlie Wakida and Lesley Yokomizo; Deputy DLNR Chairperson Libert Landgraf; Robert Lee and members of the Natural Area Reserves Commission; Jim Jacobi of the U.S. Fish and Wildlife Service; Ron Nagata of Haleakala National Park; and Chuck Stone, Larry Katahira, Steve Anderson, and Linda Cuddihy of Hawaii Volcanoes National Park.

Finally, sincerest thanks to Governor John Waihee, the State Legislature, and DLNR Chairperson William Paty for their desire and vision to preserve Hawaii's unique natural resources, and for their support of the Natural Area Reserves System.

Michael G. Buck  
Natural Area Reserves System Coordinator

APPENDIX 1  
Puu Makaala Natural Area Reserve

Transect Specifications

Transect number	Transect length(ft)	No. of stations	Natural communities surveyed
1	3444	21	Ohia/Hapuu Montane Wet Forest
2	2624	17	Ohia/Hapuu Montane Wet Forest
3	4428	28	Ohia/Hapuu Montane Wet Forest
4	7708	48	Koa/Ohia & Ohia/Hapuu Montane Wet Forests
5	4428	28	Ohia/Hapuu Montane Wet Forest
6	4428	28	Ohia/Hapuu Montane Wet Forest
7	4428	28	Ohia/Hapuu Montane Wet Forest
8	4428	28	Ohia/Hapuu Montane Wet Forest
9	2460	16	Ohia/Hapuu Montane Wet Forest
10	2296	15	Koa/Ohia Montane Wet Forest
A	n/a	1	Koa/Ohia Montane Wet Forest
B	n/a	1	Carex alligata Montane Wet Grassland
C	n/a	1	Ohia/Hapuu Montane Wet Forest

Survey Participants

Michael Buck - Survey Forester, DOFAW  
 Sam Gon III - Ecologist, HHP  
 Steve Perlman - Field Coordinator, HHP  
 Thane Pratt - Ornithologist, DOFAW

DOFAW = Hawaii State Department of Forestry and Wildlife  
 HHP = Hawaii Heritage Program, The Nature Conservancy of Hawaii



Puu Makaala Natural Area Reserve  
Sample Survey Forms

TRANSECT STATION FIELD FORM      Time Start: \_\_\_\_\_ End: \_\_\_\_\_ Date: \_\_\_\_\_  
 NC Name: \_\_\_\_\_ MAR Name: \_\_\_\_\_  
 Observer(s): \_\_\_\_\_  
 Transect#: \_\_\_\_\_ Station#: \_\_\_\_\_ Elevation: \_\_\_\_\_ Bearing: \_\_\_\_\_  
 Description Line: \_\_\_\_\_ Photo #: \_\_\_\_\_  
 INCIDENTAL OBSERVATIONS: \_\_\_\_\_  
 CHK ITEM: \_\_\_\_\_ REMARKS: \_\_\_\_\_

ASPECT		SLOPE	CANOPY CLOSURE	TOPOGRAPHIC POSITION	CANOPY STATURE	SOIL MOISTURE
Birds		FLAT	DENSE	CREST	<1 M	INUNDATED
Native Inverts		GENTLE	CLOSED	UPPER SLP	1-2.5 M	SATURATED
Small Mammals		MDD	OPEN	MID SLP	2.5-5 M	MOIST
Non-native Inverts		STEEP	SCATTER	LOW SLP	5-10 M	MOIST-DRY
Fire		VERT	VERYS	BOTTOM	>10 M	DRY
Erosion						
Human Influence						
Add'l Survey Needs						
	NO CHG	NO CHG	NO CHG	NO CHG	NO CHG	NO CHG

TRANSECT STATION FIELD FORM

Observer(s): \_\_\_\_\_

NC Name: \_\_\_\_\_

Time Start: \_\_\_\_\_ End: \_\_\_\_\_ Date: \_\_\_\_\_

NAR Name: \_\_\_\_\_

Transsect#: \_\_\_\_\_ Station#: \_\_\_\_\_ Elevation: \_\_\_\_\_ Bearing: \_\_\_\_\_

Description Line: \_\_\_\_\_

INCIDENTAL OBSERVATIONS: \_\_\_\_\_ Photo #: \_\_\_\_\_

CHK ITEM: \_\_\_\_\_

REMARKS: \_\_\_\_\_

[illegible]

```

TRANSMIT SUBSTATION FIELD FORM
NC Name: _____ Date: _____
NAR Name: _____ End: _____
Observer(s): _____ Transact#: _____
COVER CLASS CODES: 1 = C13 2 = 1-51 3 = 2-23
                     4 = 25-50 5 = 50-75 6 = 75-90
                     (FOR USE BELOW)
STATION NUMBER: _____
ITEM: _____

```

[illegible]

APPENDIX 3  
Puu Makaala Area  
Plant Species List

This species list was compiled from available literature sources, personal communication with botanists familiar with the area (backed by specimen verification for rare plants), and field identification during this NARS field survey. Rare plants (less than 3,000 individuals, or known from fewer than 20 locations worldwide) with specific location information are noted by '+' and are either in the reserve or its adjacent area (see the rare plants table for those confirmed in the reserve). Rare plants thought to occur in the reserve but which lack specific location information, are noted by '#' in the status column.

Due to subjective location information, some non-rare species included on this list may not actually be in the reserve. Plants and their associated vegetation types reported from literature for the area, but not confirmed during this survey, are noted with an 'x'. Plants reported for the area without an associated vegetation type are assigned to the natural community they would most likely occur in with a '?'.  
 Description of the natural communities are in the text. Taxonomy follows Wagner et al. (in press) and Wagner and Wagner (unpub.).

Status	Taxon	Ohia/Hapu'u Wet Forest	Koa/Ohia Wet Forest	Carex Wet Grassland
E	Acacia koa		*	*
E	Adenophorus hymenophylloides	*	x	
+	Adenophorus periens	?	?	?
E	Adenophorus pinnatifidus	*	x	
E	Adenophorus tamariscinus	*	x	
E	Adenophorus tripinnatifidus	*		
N	Ageratina riparia	*	*	
N	Ageratum conyzoides	*	x	
E	Alyxia oliviformis	*	x	
N	Andropogon scoparius	*		
N	Andropogon virginicus	*	*	*
N	Anemone hupehensis	*	*	*
E	Anoectochilus sandwicensis	?	?	?
N	Anthoxanthum odoratum	*		
E	Antidesma platyphyllum	x		
N	Arundina graminifolia	*	*	
E	Asplenium contiguum	*	x	
#	Asplenium fragile var. insulare	?	?	?
E	Asplenium lobulatum	*	*	

+ = Rare      N = Non-native      I = Indigenous      E = Endemic

\* = Confirmed in NARS field survey    x = Cited in literature sources  
 ? = Cited in literature; needs confirmation in natural community

STATUS	TAXON	Ohia/Hapu'u Wet Forest	Koa/Ohia Wet Forest	Carex Wet Grassland
	E Asplenium macraei	x		
	E Asplenium praemorsum	x		
+	E Asplenium schizophyllum	?	?	?
	? Asplenium spp.	*	*	
	E Asplenium subcaudatum	*		
	E Asplenium unilaterale	*		
	E Astelia menziesiana	*	*	
	N Athyrium japonicum	*	*	
	E Athyrium microphyllum	*	*	
	E Athyrium sandwichianum	*	*	
	N Axonopus affinis	*	*	
#	E Bidens hawaiiensis	?	?	?
#	E Bobea timonioides	?	?	?
#	E Botrychium subbifoliatum	?	?	?
	N Brassica spp.	x		
	E Broussaisia arguta	*	*	
	N Buddleia asiatica	*	*	
	E Callistopteris baldwinii	*		
	E Cardamine flexuosa	*		
	E Carex alligata	*	*	*
	E Carex wahuensis	?	?	?
	N Castilleja arvensis	*		
	N Centella asiatica	*		
	E Charpentiera obovata	*		
	E Cheirodendron trigynum	*	*	
	E Cibotium chamissoi	*	*	
	E Cibotium glaucum	*	*	*
	E Cibotium hawaiiense	*	x	
#	E Claoxylon sandwicense	?	?	?
+	E Clermontia lindseyana	?	?	?
	E Clermontia montis-loa	*		
	E Clermontia parviflora	*	x	
+	E Clermontia peleana	?	?	?
	E Clermontia spp.	*	*	
	N Clidemia hirta	*		
	E Coniogramme pilosa	*	*	
	E Coprosma ernodeoides	?	?	?
	E Coprosma ochracea	*	*	*
	E Coprosma pubens	*		
	E Coprosma rhynchocarpa	*	*	*
	N Crassocephalum crepidioides	*	*	
	E Ctenitis latifrons	x	x	
	E Ctenitis rubiginosa	?	?	?
	N Cuphea carthagenensis	*	x	
	E Cyanea degeneriana	*	*	
+	E Cyanea giffardii	?	?	?
	E Cyanea pilosa	*		
	E Cyanea pilosa ssp.	*		

+ = Rare      N = Non-native      I = Indigenous      E = Endemic

\* = Confirmed in NARS field survey    x = Cited in literature sources  
 ? = Cited in literature; needs confirmation in natural community



STATUS		TAXON	Ohia/Hapu Wet Forest	Koa/Ohia Wet Forest	Carex Wet Grassland
		longipedunculata			
#	E	Cyanea solanacea	?	?	?
	E	Cyanea spp.	x		
+	E	Cyanea stictophylla	x		
+	E	Cyanea tritomantha	*		
	N	Cyperus haspan	*	*	
	N	Cyperus kyllinga	x	x	
	I	Cyperus polystachyus	*		
	N	Cyperus spp.	x	x	
+	E	Cyrtandra giffardii	*		
	E	Cyrtandra lysiosepala	*		
	E	Cyrtandra paludosa	*	*	
	E	Cyrtandra platyphylla	*	*	
	E	Cyrtandra spp.	*	x	
	E	Datura candida	*		
	E	Deschampsia australis	x		
	N	Desmodium spp.	*	*	
	I	Dicranopteris linearis	*	*	
	N	Digitaria spp.	*		
	E	Diplopterygium pinnatum	*		
	N	Drymaria cordata var. pacifica	*	x	
	E	Dryopteris acutidens	*		
	?	Dryopteris fusco-atra	*	*	
	E	Dryopteris glabra	*		
	E	Dryopteris hawaiiensis	?	?	?
	?	Dryopteris spp.	*	x	
	E	Dryopteris wallichiana	*		
	E	Dubautia scabra	*	*	
	I	Elaphoglossum alatum	*	x	
	E	Elaphoglossum hirtum	*	*	
	E	Elaphoglossum pellucidum	*		
	E	Elaphoglossum wawrae		*	
	?	Eleocharis spp.	*		
	E	Embelia pacifica	*		
	N	Erechtites valerianifolia	*	*	
+	E	Eurya sandwicensis	*		
	E	Fragaria chiloensis var. sandwicensis	*	*	
	N	Fragaria spp.	*		
	N	Fraxinus uhdei	*		
	E	Freycinetia arborea	*	x	
	N	Gnaphalium purpureum	*	*	
	E	Gonocormus prolifer	*		
	E	Grammitis hookeri	*	*	
	E	Grammitis tenella	*	x	
	N	Hedychium flavescens	*		
	N	Hedychium gardnerianum	x		
	E	Hedyotis axillaris	x	x	

+ = Rare      N = Non-native      I = Indigenous      E = Endemic

\* = Confirmed in NARS field survey    x = Cited in literature sources  
 ? = Cited in literature; needs confirmation in natural community

STATUS	TAXON	Ohia/Hapu Wet Forest	Koa/Ohia Wet Forest	Carex Wet Grassland
E	Hedyotis affinis	*	x	
E	Hedyotis centranthoides	*		
N	Holcus lanatus	*		
E	Huperzia phyllanthum	*		
E	Huperzia polytrichoides	x	x	
N	Hypericum degeneri	*	*	
N	Hypochaeris radicata	*	*	
E	Ilex anomala	*	*	
+ E	Joinvillea ascendens ssp. ascendens	?	?	?
N	Juncus effusus	*	*	
E	Korthalsella complanata		*	
E	Labordia hedyosmifolia	*	*	
E	Labordia hirtella	*		
E	Labordia spp.	*		
E	Liparis hawaiiensis	x	x	
N	Lotus uliginosus	*		
N	Ludwigia octivalvis	*		
N	Ludwigia palustris	*	*	
I	Lycopodium cernuum	*		x
?	Lycopodium spp.		*	
I	Lycopodium venustulum	*		
I	Machaerina angustifolia	*		
E	Marattia douglasii	*	*	
E	Mecodium recurvum	*	x	
N	Melastoma spp.	*		
E	Metrosideros polymorpha	*	*	*
N	Microlaena stipoides	*	*	
I	Microlepis strigosa	*	x	
I	Myoporum sandwicense	*	*	
E	Myrsine spp.	*		
E	Myrsine emarginata	*		
E	Myrsine lessertiana	*	*	*
E	Myrsine sandwicensis	*		
I	Nephrolepis cordifolia	*	x	
I	Nertera grandensis	*	*	
E	Nothocestrum longifolium	*	x	
I	Odontosoria chinensis	*	x	
I	Ophioglossum pendulum	*	x	
N	Paspalum conjugatum	*		
N	Paspalum urvillei	*	*	
N	Passiflora edulis	*		
N	Passiflora ligularis	*	x	
N	Passiflora mollissima	*	*	
E	Pelea clusiifolia	*		
E	Pelea pseudoanisata	*	*	
E	Pelea spp.	*	*	
+ E	Pelea zahlbruckneri	?	?	?

+ = Rare      N = Non-native      I = Indigenous      E = Endemic

\* = Confirmed in NARS field survey    x = Cited in literature sources

? = Cited in literature; needs confirmation in natural community

STATUS		TAXON	Ohl'a/Hapu'u Wet Forest	Koa/Ohl'a Wet Forest	Carex Wet Grassland
	N	Pennisetum clandestinum	*		
	E	Peperomia hypoleuca	*		
	E	Peperomia macraeana	*		
	E	Peperomia membranacea	*		
	E	Peperomia spp.	*	*	
	E	Perrottetia sandwicensis	*	*	
	N	Phaius tankervilleae	*	x	
	E	Phyllostegia ambigua	?	?	?
#	E	Phyllostegia brevidens	?	?	?
+	E	Phyllostegia floribunda		*	
#	E	Phyllostegia macrophylla		*	
+	E	Phyllostegia racemosa	*	*	
+	E	Phyllostegia velutina		*	
	E	Phyllostegia vestita	?	?	?
	N	Physalis peruviana	x	x	
	E	Phytolacca sandwicensis	x		
	N	Pinus spp.	*		
	E	Pipturus albidus	*	*	*
	E	Pisonia brunoniana	x		
	N	Pityrogramma austroamericana	*		
	N	Plantago major	*	*	
	E	Platydesma spathulata	*	x	
	I	Pleopeltis thunbergiana	*	*	
	N	Pluchea symphytifolia	*		
	N	Poa spp.		x	
	N	Polygonum punctatum	*	x	
	E	Polypodium pellucidum	*	*	
	E	Pritchardia beccariana	*		
	N	Prunella vulgaris	*	*	
	N	Prunus cerasifer x salicina		*	
	N	Psidium cattleianum	*		
	I	Psilotum complanatum	*	x	
	I	Psilotum nudum	*		
	E	Psychotria hawaiiensis	*	*	
	I	Pteris cretica	?	?	?
	I	Pteris excelsa	*		
	E	Pteris irregularis	*	*	
	N	Pteris vittata	*		
#	E	Ranunculus hawaiiensis	?	?	?
	E	Reynoldsia sandwicensis	?	?	?
	I	Rhynchospora rugosa spp. lavarum	*		
	N	Rubus argutus	*	x	
	N	Rubus ellipticus	*	x	
	E	Rubus hawaiiensis	*	*	
	N	Rubus rosifolius	*	*	
	N	Rumex acetosella	?	?	?
	E	Rumex giganteus	*	*	

+ = Rare      N = Non-native      I = Indigenous      E = Endemic

\* = Confirmed in NARS field survey    x = Cited in literature sources  
 ? = Cited in literature; needs confirmation in natural community

STATUS	TAXON	Ohia/Hapu'u Wet Forest	Koa/Ohia Wet Forest	Carex Wet Grassland
N	Sacciolepis indica	*		
E	Sadleria cyatheoides	*		
E	Sadleria pallida	*	x	
E	Sadleria souleyetiana	*	*	*
E	Sadleria spp.	x	*	
N	Salvia spp.	*		
E	Schiedea diffusa	x		
E	Selaginella arbuscula	*		
N	Selaginella kraussiana		*	
N	Sequoia sempervirens		*	*
N	Setaria geniculata	*		
N	Setaria palmaefolia	*	*	*
+ E	Sicyos alba	*		
E	Sicyos spp.	x	*	
E	Smilax melastomifolia	*		
N	Solanum americanum	x	x	
E	Sphaerocionium lanceolatum	*	x	
N	Sporobolus africanus	*		
N	Stachytarpheta jamaicensis	*		
E	Stenogyne calaminthoides	*	*	
+ E	Stenogyne macrantha	*		
E	Stenogyne rugosa	?	?	?
+ E	Stenogyne scrophularioides	?	?	?
E	Stenogyne spp.	x		
E	Sticherus owhyensis	*		
E	Styphelia tameiameia	*		
E	Tetraplasandra hawaiiensis	?	?	?
E	Tetraplasandra kawaiiensis	*		
E	Tetraplasandra oahuensis	*		
I	Thelypteris cyatheoides	*	x	
E	Thelypteris globulifera	*		
E	Thelypteris keraudreniana	*		
E	Thelypteris sandwicensis	*	*	
N	Tibouchina urvilleana	*		
E	Touchardia latifolia	*	x	
E	Trematolobelia grandifolia	*	x	
N	Tritonia crocosmiflora	*		
I	Uncinia uncinata	*	*	
E	Urera glabra	*		
E	Vaccinium calycinum	*	*	
E	Vaccinium reticulatum	*		
E	Vandenboschia davallioides	*	x	
N	Veronica serpyllifolia	*		
+ E	Vicia menziesii		x	
E	Wikstroemia sandwicensis	*		
E	Xiphopteris saffordii	*	x	
# E	Xylosma hawaiiense	x		
N	Youngia japonica	*	x	

+ = Rare      N = Non-native      I = Indigenous      E = Endemic

\* = Confirmed in NARS field survey    x = Cited in literature sources  
 ? = Cited in literature; needs confirmation in natural community

APPENDIX 4  
Puu Makaala Area  
Bird Species List

Status	Taxon	Common Name	Source
N	<u>Acridotheres tristis</u>	Common Myna	x
N	<u>Alauda arvensis</u>	Eurasian Skylark	x
+E	<u>Buteo solitarius</u>	`Io, Hawaiian Hawk	*
N	<u>Callipepla californica</u>	California Quail	x
N	<u>Cardinalis cardinalis</u>	Northern Cardinal	*
N	<u>Carpodacus mexicanus</u>	House Finch	x
E	<u>Chasiempis sandwichensis</u>	`Elepaio	*
	<u>    ridgwayi</u>		
N	<u>Garrulax canows</u>	Melodious Laughing-thrush	x
N	<u>Geopelia striata</u>	Zebra Dove	x
+E	<u>Hemignathus munroi</u>	`Akiapola`au	x
E	<u>Hemignathus virens</u>	Common `Amakihi	x
E	<u>Himatione sanguinea</u>	`Apapane	*
	<u>    sanguinea</u>		
N	<u>Leiothrix lutea</u>	Red-billed Leiothrix	*
N	<u>Lonchura punctulata</u>	Nutmeg Mannikin	x
E	<u>Myadestes obscurus</u>	`Oma`o, Hawaiian Thrush	*
+E	<u>Oreomystis mana</u>	Hawaii Creeper	x
N	<u>Phasianus colchicus</u>	Ring-necked Pheasant	x
+E	<u>Psittirostra psittacea</u>	`O`u	x
E	<u>Vestiaria coccinea</u>	`I`iwi	*
N	<u>Zosterops japonicus</u>	Japanese White-eye	*

+ = Rare                          E = Endemic                          N = Non-native  
x = Cited in Scott et al. (1986)   \* = Confirmed in NARS field survey